Conceptual Design Report

Muon Cooling Linac Area
Fermi National Accelerator Laboratory
Project No. AG-GPP
for the

U.S. Department of Energy, Batavia Area Office

Prepared by: FNAL, Beam Division

FNAL Approval

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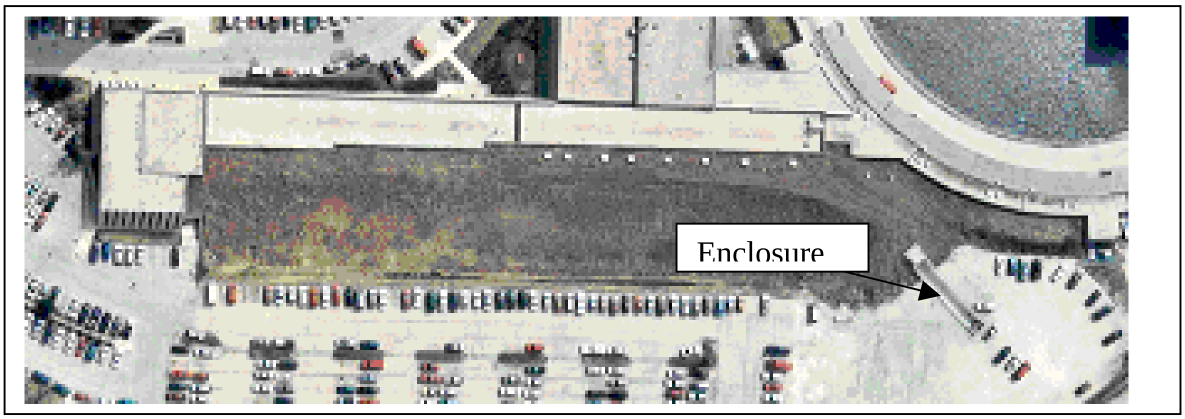
Section I Project Description

This project would involve the construction, installation, and operation of a new beamline enclosure for small-scale research & development projects in the Linac area at Fermilab. The MuCool Test Area facility will be built in the next eighteen months. The type of funding, the funding profile and the need to provide space for the Liquid Hydrogen Absorber Test in the very near future dictate splitting the construction into two phases: Phase I (February-September 2001) and Phase II (October 2001-June 2002)

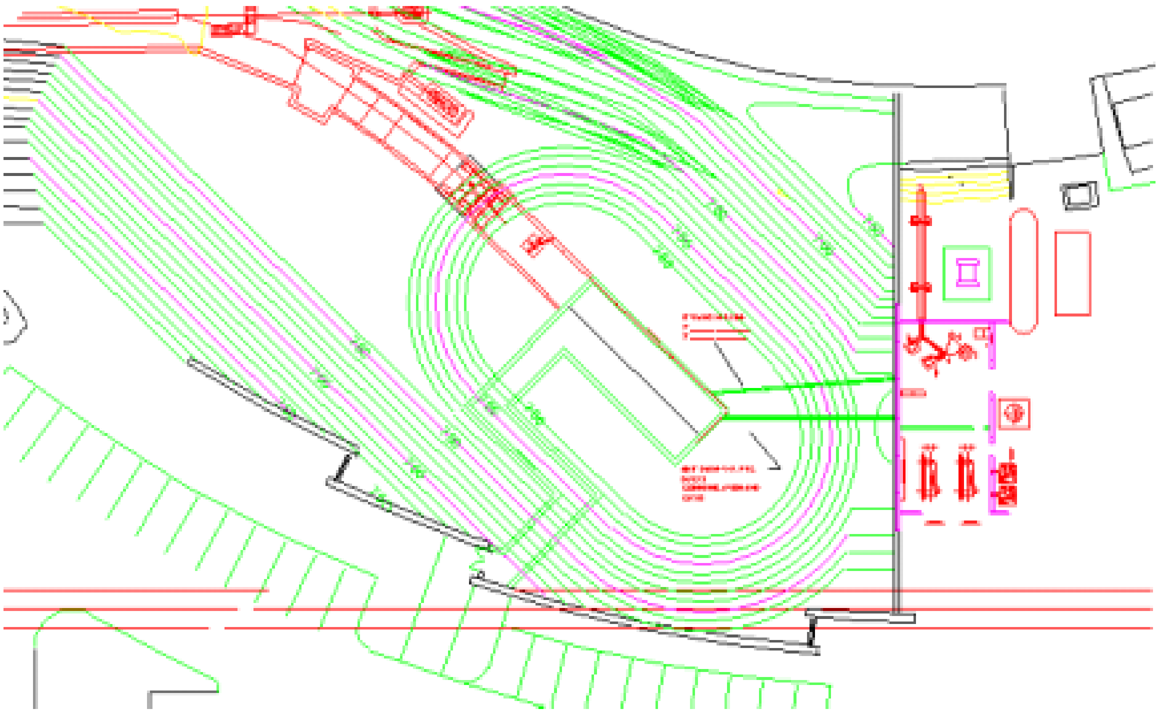
Section II Detailed Description and Purpose of Facility



The proposed facility would be used initially to test a liquid hydrogen absorber for cooling of muon beams for the Neutrino Factory/Muon Collider; to test high gradient RF cavity structures and high-gradient cryogenically-cooled/superconducting cavities; and to test performance of this equipment with beam. It is possible that there will be requests to do work for others at this facility in the future, and it is expected that in the long term it will continue to be used for small-scale research and development projects unrelated to the Neutrino Factory/Muon Collider.

a. Phase I

The facility would be constructed in two phases: The first phase (March-2001 September 2001) would involve turning part of the existing Linac south access ramp into an enclosure to create a facility for installation and testing of a liquid hydrogen absorber. The existing concrete ramp would be demolished and replaced with a stronger one, and new concrete walls and a concrete roof would be built around it. The new enclosure will be built to support the weight of shielding equivalent to nineteen feet of dirt. The rebuilt ramp/enclosure in Phase I would be 31 feet long starting from the existing shielding blocks. The two ends of this part of the enclosure will be temporary structures. The end next to the shielding blocks has to allow for temporary removal of the shielding blocks in Phase II for placement of the beam line. The other end will be removed as soon as the rest of the enclosure is built in Phase II. In addition in Phase I, support structures will be constructed adjacent to the enclosure, including a small service building (1250 square feet) to house a helium refrigerator, accompanied by a liquid nitrogen dewar and a paved area to accommodate the LN2 truck (750 square feet). Refrigeration equipment would be moved from PS4 to the new building. Limited excavation would be required to construct the new enclosure and support structures. A new 1500-KVA transformer will be installed on a new pad (up to approximately 200 square feet) adjacent to the new service building to provide electric power for the facility. Industrial cooling water supply and return lines would connect the refrigerator building with the existing Linac or Booster gallery (length and routing to be determined). The new enclosure built in this phase will house the liquid hydrogen absorber; engineering tests of the liquid hydrogen absorber without beam will be conducted after this first phase of construction is completed.



Red objects are existing objects and objects that will be built as Phase I. Phase II objects are shown here as green objects

b. Phase II

The second phase (October 2001-June 2002) would entail expansion of the facility to accommodate testing of larger components and would include tests with beam. An additional 900 square feet-experimental area would be constructed downstream of the phase 1 enclosure, extending for an additional 30 feet. The phase 1 enclosure and service building and the new phase 2 enclosure would all be covered with earth shielding during phase 2. The shielding, equivalent to nineteen feet of dirt, is designed to accommodate the maximum intensity deliverable by the Linac (50 mA, 50 microseconds, 15 Hz). Magnets recycled from the old Main Ring accelerator will be used as shielding in some locations to reduce the amount of soil that would otherwise be needed. This will allow the height of the berm to be comparable to that of the existing Linac berm with which it will connect. It will also minimize the separation needed between the enclosure and the service building, thereby reducing the total footprint of the facility. A concrete retaining wall would be constructed to separate the berm from the parking lot. A labyrinth would be built to provide access to and egress from the experimental enclosure. Again, limited excavation would be required for construction of the new enclosure and supporting labyrinth. The proposed action would also involve the acquisition and installation of a number of beamline components. These components would include beam tubes, various magnets, beam stands, and vacuum pumps. A beam absorber (beam dump) will be installed below the level of the enclosure floor which will give more than nineteen feet dirt equivalent shield. Installation of cooling water systems would be necessary for the magnets and power supplies. RF power and beam would be brought over from the Linac enclosure (no excavation involved). Operation of this beamline would be entirely parasitic to the current operation of the Linac, i.e., there would be no changes in the existing energy and intensity capabilities of the Linac.

c. Choice of Location

Other locations on site might be feasible for this facility, but this one was selected because of its proximity to a proton beam and RF power sources as well as other utilities. All construction would occur in an already disturbed area, namely the parking area west of the south end of the Linac and Booster West Gallery. It would consume a portion of the parking lot; between 39 and 44 parking spaces would be permanently eliminated. A decision on whether to replace them has not yet been made. The overall footprint of the new berm, which would encompass all of the new structures, would be something on the order of 140 ft x 200 ft, or roughly 28,000 square feet. Additional space in the parking area (up to an additional 28,000 square feet) would be required during the construction phase of the project to provide space for contractor facilities, equipment deployment, soil stockpile, etc. Any conflicts with existing buried utilities in the areas to be excavated would be resolved by relocating the utilities or adjusting the design. Soil for the shielding berm would come from an on-site stockpile.

d. Physic Motivation

1. Need for Accelerator Development

Within the next decade the Large Hadron Collider (LHC) at CERN will surpass Fermilab's Tevatron as the world's premier exploratory particle accelerator. The long-term viability of Fermilab during this period can be assured only if we plan for a future accelerator capable of surpassing the LHC's research capabilities and consistent with the progress of current and near-future experiments. Three major contenders under consideration for such a machine are a next-generation hadron collider (VLHC), a linear electron-positron collider, and, perhaps most ambitious of the three, a muon collider, the first stage of which would be a neutrino factory.

2. Muon Cooling

Accelerating muons to high energies represents a unique challenge. To this date, all large particle accelerators have accelerated stable charged particles. Muons are produced with a large angular spread, and before a muon beam can be injected into an accelerator, its angular spread must be substantially reduced -- a technique that goes by the name of "beam cooling." Since on average muons live only about 2 microseconds, the techniques for beam cooling that have been developed in the past (and used notably for antiprotons) are too slow by many orders of magnitude. The only method known that is fast enough to cool muons before they decay uses ionization energy loss as a "muon brake" as the muon beam passes through specially-configured energy-absorbing material.

Muons can penetrate far more deeply into material than hadrons or electrons. As they do so, they gradually lose energy at a small, but consistent and predictable, rate. We want to take advantage of this fact by developing a muon cooling channel, consisting of energy absorbers (to slow down the muons) alternating with strong electric fields (to replace the lost muon momentum). To minimize scattering of the muons by close encounters with atomic nuclei, we should use material with the lowest possible atomic number. In this way, the muon momentum transverse to the beam direction is reduced relative to the longitudinal momentum, thereby reducing the angular spread of the muon beam - i.e., the beam is "cooled." We propose to use liquid-hydrogen (LH2) energy absorbers and high-gradient radio-frequency (RF) resonant cavities, keeping the muon beam focussed as it passes through the channel by means of magnetic fields provided by superconducting solenoids. Though each of these elements is a known technology, their combination in such a cooling channel, and the required operational parameters, challenges the limits of current technology. Therefore, a serious R&D program is necessary to work out the engineering difficulties for each of the cooling-channel components and assess the limits (or work around the limits) of various cooling-channel configurations now being considered.

3. Absorber Test Facility

One pressing need crucial to the success of our endeavors has been to obtain a dedicated test area for component development. The muon-cooling RF R&D effort has made great progress by having such an area (Lab G). The liquid-hydrogen-absorber effort requires an area with special facilities to accommodate the liquid-hydrogen safety concerns and cryogenics. As part of the series of tests in the development of the RF cavities, the LH2 absorbers, and the high-field solenoids, we will be performing a "high-power" test involving an intense particle beam. Ideally, of course, we'd like muons, but a sufficiently intense muon beam does not exist, and in practice most of the design and engineering issues can be addressed using a beam of any type of charged particle as long as the beam intensity is sufficiently high.

The new absorber test facility now under construction will provide a large and needed boost to the efforts of those working on muon cooling (essential for both muon colliders and neutrino factories), not only for the MUCOOL collaboration at Fermilab, but for the entire Neutrino Factory and Muon Collider Collaboration. The siting of the facility will allow us eventually to run beam tests parasitically to Tevatron Collider operation using the 400 MeV FNAL linac. In the longer term it can also be used as a facility for other R&D beyond MUCOOL and the technical challenges of a neutrino factory or muon collider.

The installation of the test facility will proceed in several stages. In the first stage, a small space will be enclosed, and a refrigeration system set up, for the assembly and testing of the LH2-absorber prototypes. The second stage is to increase the available floor space to accommodate prototype RF cavities and solenoids. Following this enlargement of the laboratory, a beam transfer line from the LINAC will be installed (planned for 2002).

In addition to developing cooling-channel components, a whole new generation of beam instrumention needs to be developed, and this will be integral to the design of the cooling components themselves. Over the next three years, this test facility will be a critical focus of the entire neutrino factory/muon collider effort. In addition, the long-term use of this beamline and test area may help ease a critical shortage of low- and medium-energy test beams for detector and technology development, for both high-energy and other branches of physics.

Section III Performance Requirements

The Phase I facility will provide housing for LH2 absorber and will have operational Liquid Helium plant with cooling capacity of 400 Watts.
In Phase II, the full enclosure and shielding berm will be finished. The beam transport to the new enclosure will be installed. The shielding and beam transport will be capable of transporting 400 MeV kinetic energy H- beam of 50 mA peak current, 50 microseconds pulse length at 15 Hz with acceptable losses which do not exceed standards of radiation hazards.

Section IV Construction Schedules

1-may-2001	Enclosure of Phase I Completed
1-June-2001	Cryo Building Completed
1-July –2001	Cryo Plant Operational
1-Aug.-2001	Beginning of Liquid Hydrogen Absorber Engineering tests
30-Sep.-2001	Phase I Completed
1-Oct.-2001	Beginning of Phase II
1-Dec-2001	Enclosure of Phase II and Shielding Berm Completed
1-Feb-2002	Beginning of Beam Line Installation
1-April-2002	Beam Line Completed and Beam Line Commissioned
1-June-2002	RF Power or 201 and 805MHz in Enclosure
1-July-2002	Start of Liquid Hydrogen Absorber Beam Tests
30-Sep-2002	Phase II Completed
1-Jan-2003	Project Completed

Section V Methods of Performance

Overall project management, quality assurance and supervision of design and construction of Muon Cooling Linac Test Area will be responsibility of Fermilab through the Beams Division, which is presently responsible for the Linac/Booster Systems. Designs and installation of all hardware and software associated with this task will be overseen by Beams Division personnel.

Section IV Requirements and Assessments

Part 1 Security and Safeguards

Direction for security issues related to this project will be provided to the Beams Division by the Fermilab ES&H Section.

Part 2 Energy Conservation

In accordance with Section 0110-12 “Energy Conservation” of DOE order 6430.1A-General Design Requiremets, all elements of this project will be reviewed for energy conservation features that can be effectively incorporated into the design. Energy conservation techniques and high efficiency equipment will be utilized wherever appropriate to minimize the total energy consumption. Since no new type of equipments are involved no “Energy Conservation Report” is required.

Part 3 Life Safety

Exiting from the buildings will generally be in accordance with NFPA-101 Life Safety Code to assure adequate egress in the event of an emergency. Beams Division procedures will be followed throughout this project.

Part 4 Environmental Protection

The overall environmental impact of this project has been evaluated, and a Fermilab Environmental Notification Form was submitted to the DOE, following the National Environmental Policy Act (NEPA). The DOE has approved the project as a categorical exclusion(CX).

Part 5 Quality Assurance

In conformance with the Beams Division SQIP, the Beams Division Head has appointed Milorad Popovic as Project Leader. The Project Leader will form a team as neded to carry out the project. Project Leader must review and initial all purchase requisitions. The Project Leader will establish the means necessary to control and record changes to the project’s design criteria.

The project Coordinator will establish meetings with the Project Leader’s tema as deemed necessary to assure the technical goals of the project are being met.

The Project Leader will provided periodic written reports as requested by the Project Coordinator. The Project Coordinator will provide written semiannual reports to the Director and Beams Division Head based on the Project Leader’s reports.

Part 6 Maintenance and Operation

A maintenance program for Muon Cooling Test Area will be developed as part of this project, wich will conform to the Beams Division SQIP. All preventive maintenance, normal equipment service and emergency repairs will be completed by the Fermilab Beams Division.

Section VII Contingencies

The design criteria that have been generated for this project are based on an ongoing laboratory process that has been operating for over 20 years.
The contingency that has been included in the cost estimates is that demmed appropriate for the nature of the design criteria and is taken to be 20% before G&A overhead.

Section VIII Applicable Codes, Standards and Quality Levels

Specific applicable codes have been stated in previous sections. No codes, standards or quality levels beyond standard Fermilab requirements are deemed necessary.

Section IX Cost Estimate(GPP)

The summary of spending Profile, as estimated on 18-Feb-01 are shown bellow. For details see attached WBS. Estimates for Phase I are made by FESS and Cryo group of Beams Division. Phase II, estimates and target dates are made by Milorad Popovic based on FESS estimates for Phase I.

- Phase I, from Nov-01-00 to Sep-30-01
- Phase II, from Oct-01-01 to May-30-02

Item	Amount
H.V.Electric, Cable change&PrepWork	20000
FESS, to consulting Co. Design of Cryo Building	39800
FESS, for excavation&enclose construction, Phase I	125000
FESS, for Cryo Building construction, sqrFoot @$100	100000
Cryo, Design, Removal, Moving, Assembling	235000
Salary, 3m. Physicist	30000
Salary, 2m. Safety Person	20000
G&A	113960
Phase I, Total	**683760**
FESS, design of enclose for Phase II	20000
FESS, for excavation&enclose construction, Phase II	250000
FESS, Berm, walls, water, electric work …	200000
G&A	94000
Phase II, Total	**564000**
TOTAL PROJECT(GPP)	**1247760**